SPES Project

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On behalf of the SPES Collaboration

SNEAP 2012
Symposium for North Eastern Accelerator Personnel

30 September - 05 October 2012
INFN Laboratori Nazionali di Legnaro

The SPES* project

* SPES, Selective Production of Exotic Species,
is the latin word for Hope

- SPES is a research project centered on **basic nuclear physics and astrophysics,** with applications to :

  - production of radionuclides of medical interest;

  - generation of neutrons, for material studies, nuclear technologies and possibily health

- **SPES, together with the operation of existing machines, is the future of the laboratory**

SPES strategy

1. Develop a Neutron Rich ISOL facility delivering Radioactive Ion Beams at 10AMeV using the LNL linear accelerator ALPI as re-accelerator .

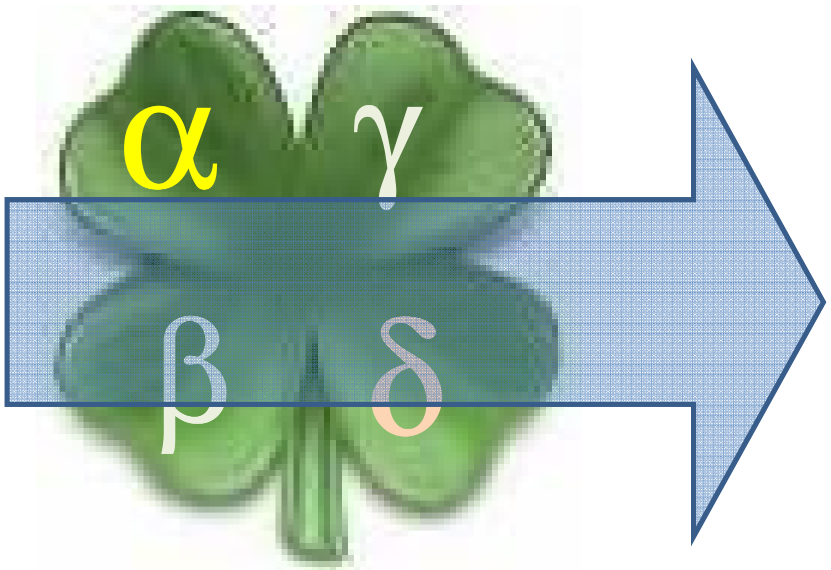
2. Make use of a Direct ISOL Target based on UCx and able to reach 10^{13} Fission/s to produce neutron rich exotic beams.

1. Apply the technology and the components of the ISOL facility to develop applications in neutron production and medicine.

Exotic nuclei

ISOL facility for
Neutron rich nuclei by
U fission 10^{13} f/s

high purity beam
Reacceleration up to
$\geq$10 MeV/u



Applications

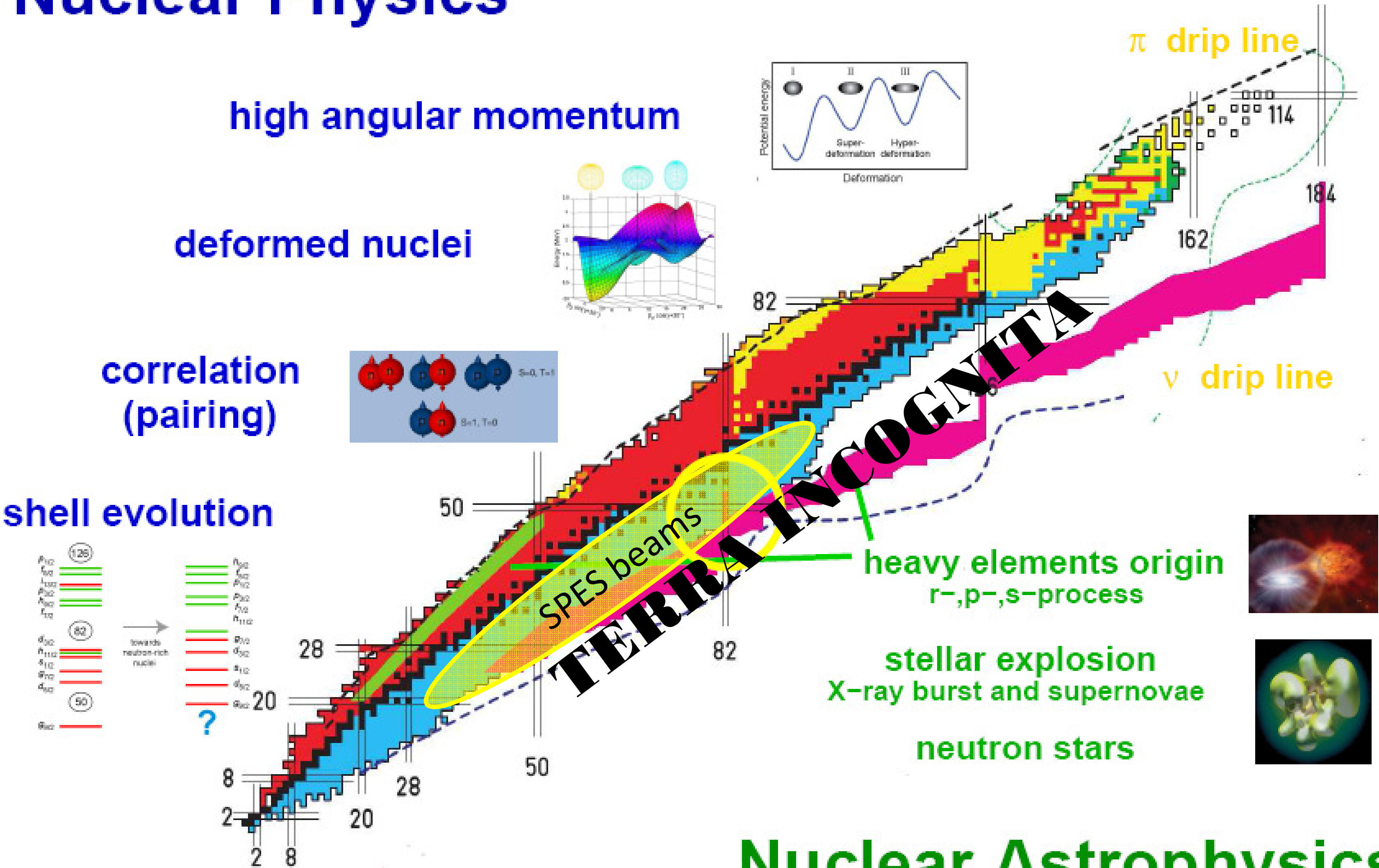
Proton and neutron
facility for applied
physics

Radioisotope
produduction
& Medical
applications

SPES

Selective Production of Exotic Species

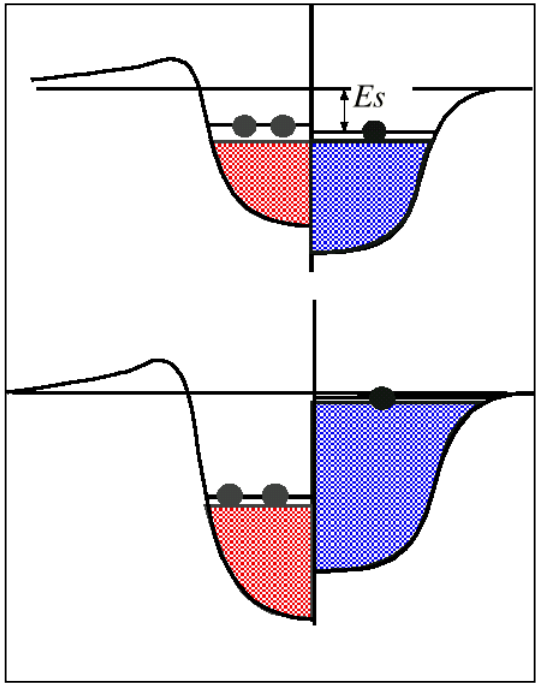
Nuclear Physics



Nuclear Astrophysics

Qualitative Difference Near the Neutron-Dripline

protons neutrons



Stable nuclei:

N/Z ≈ 1 - 1.5, $S_p \approx S_n \approx 6 - 8$ MeV

- Homogeneously mixed protons and neutrons
- Good mean-field description
- Good “single-particle” picture (magic numbers)
- Large gaps between major shells
- Empirical shell-model interactions

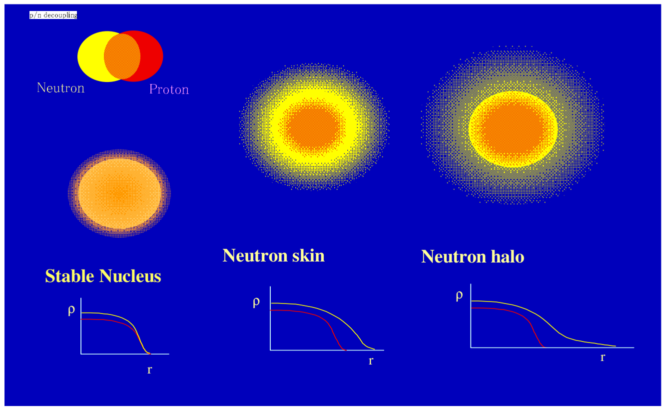
Very neutron-rich nuclei:

N/Z ≈ 2 - 2.5, S_n << 1 MeV

- Diffuseness of neutron distribution (neutron skins & halos)
- More states near the Fermi surface
- Breakdown of the single-particle description
- Redefinition or disappearance of magic numbers
- Unknown shell-model interactions

Nuclear Physics with radioactive beams:

- ❑ Exploring the limits of nuclear existence
- ❑ Exploring nuclei with unusual properties
- ❑ Exploring changes in shell structure
- ❑ Exploring nuclear shapes
- ❑ Exploring spin-isospin modes of excitation



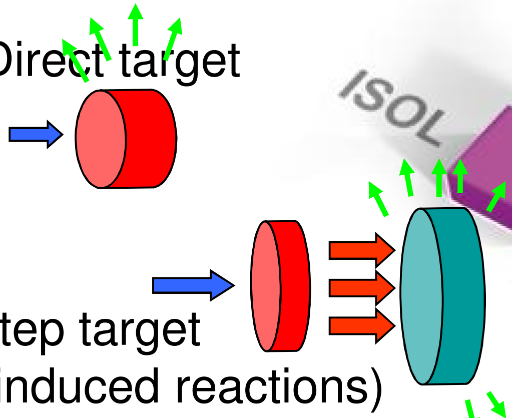
How to produce nuclei far from the stability line?

1 Perform a Nuclear reaction
2 reaction products are mainly unstable and far from the stability valley
3 Produce a secondary beam using the reaction products
4 Perform a nuclear reaction between the radioactive beam and a stable target

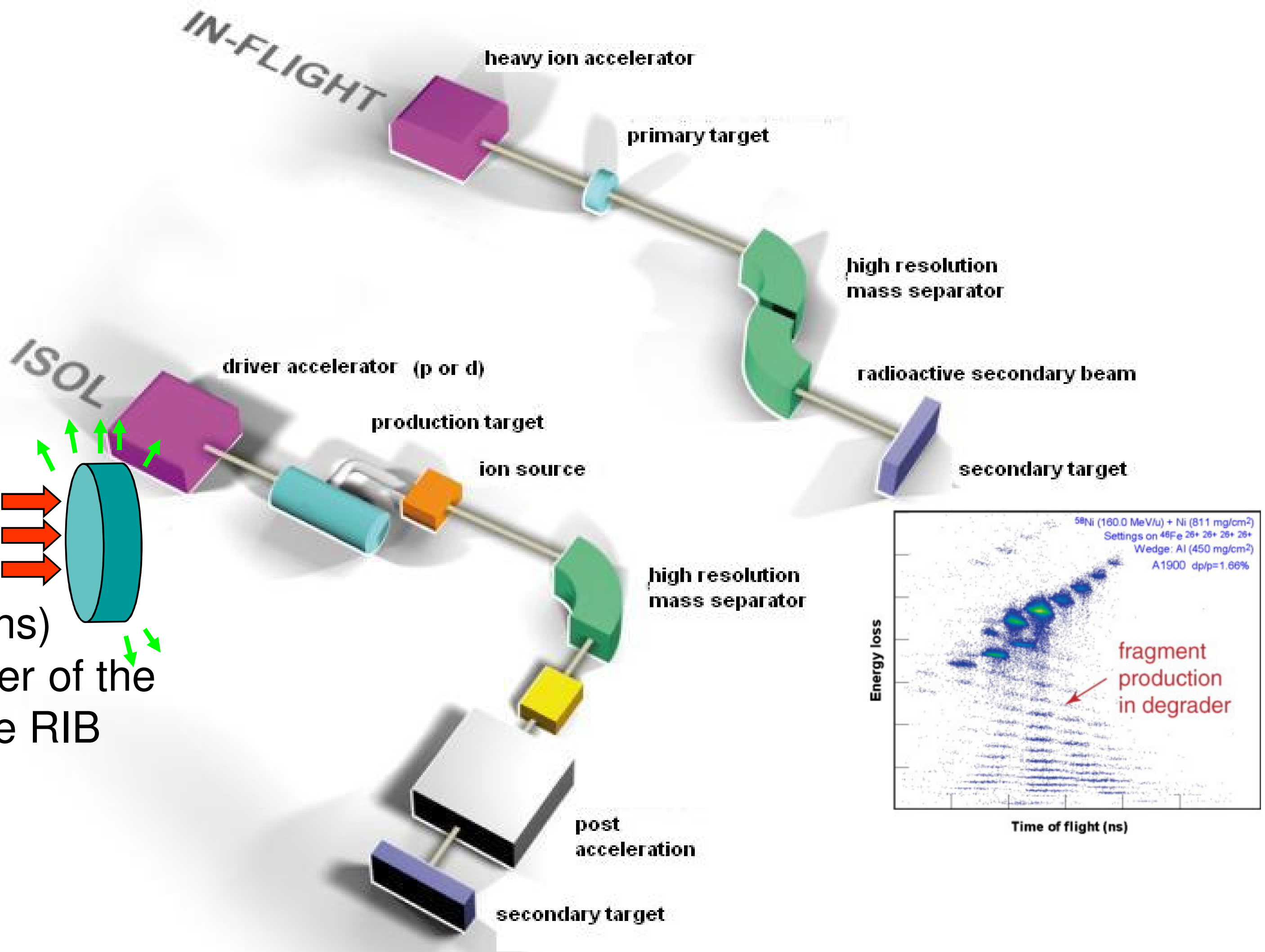
5 neutron-rich beams are mainly produced by Uranium fission

In flight projectile fragmentation	Isotope Separation On Line
High energy	Low – high energy
Fast process	Slow process
Beams not well defined	Beams (well) defined
Cocktail beams	

Radioactive Ion Beam production methods

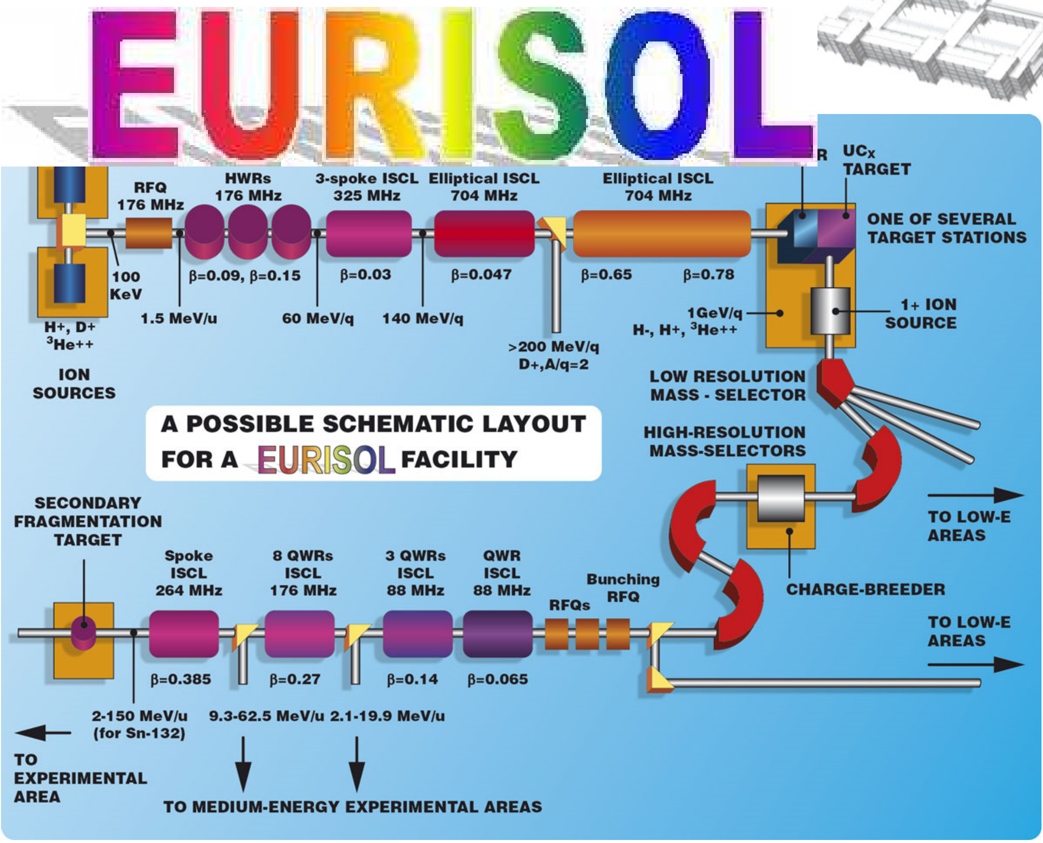


Decoupling the power of the driver beam from the RIB production target



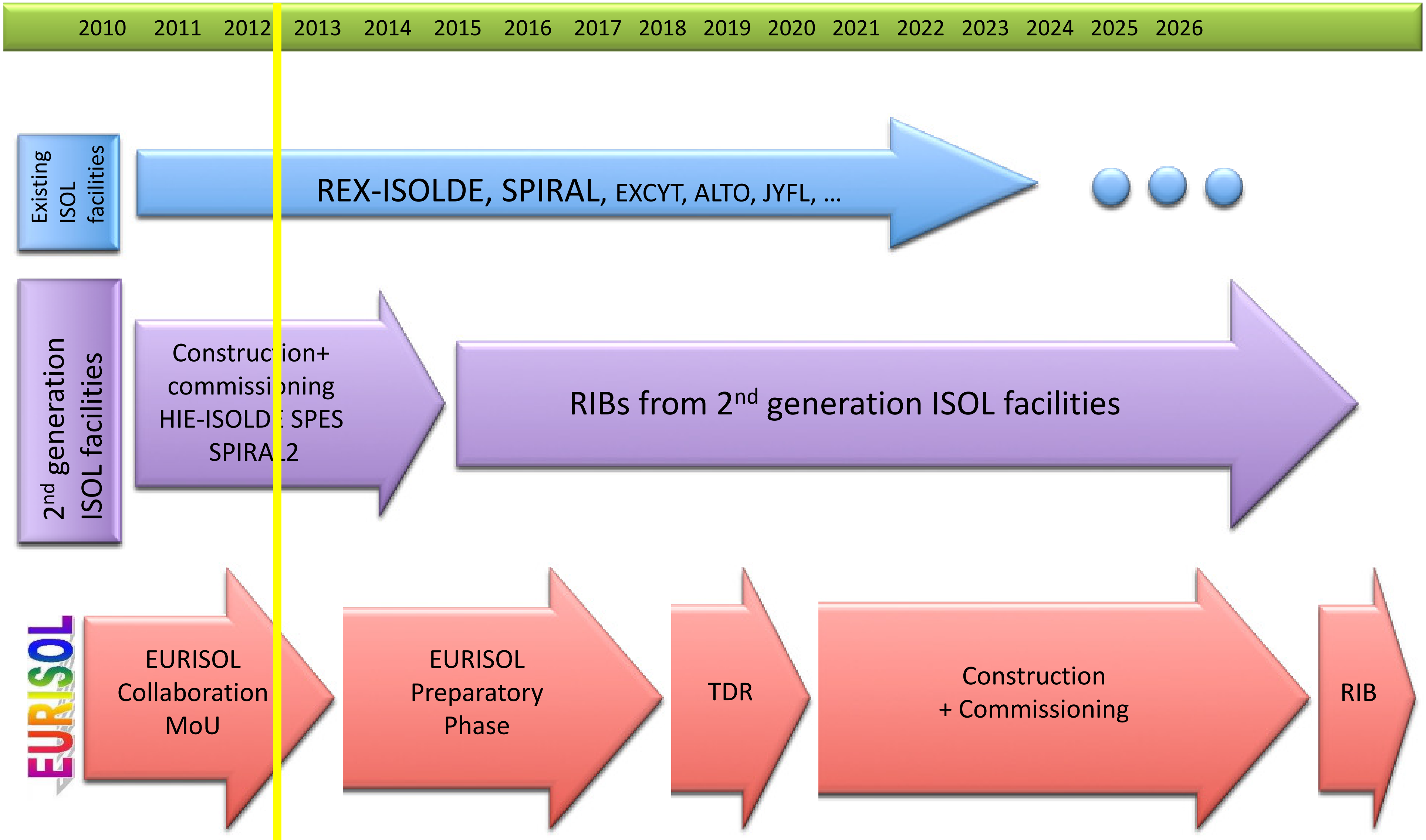
Nuclear Physics European Coordination Committee

European ISOL facility



European In Flight facility

The NuPECC
Timeline for European ISOL RIB facilities



Second generation ISOL facilities in Europe (UCx target)

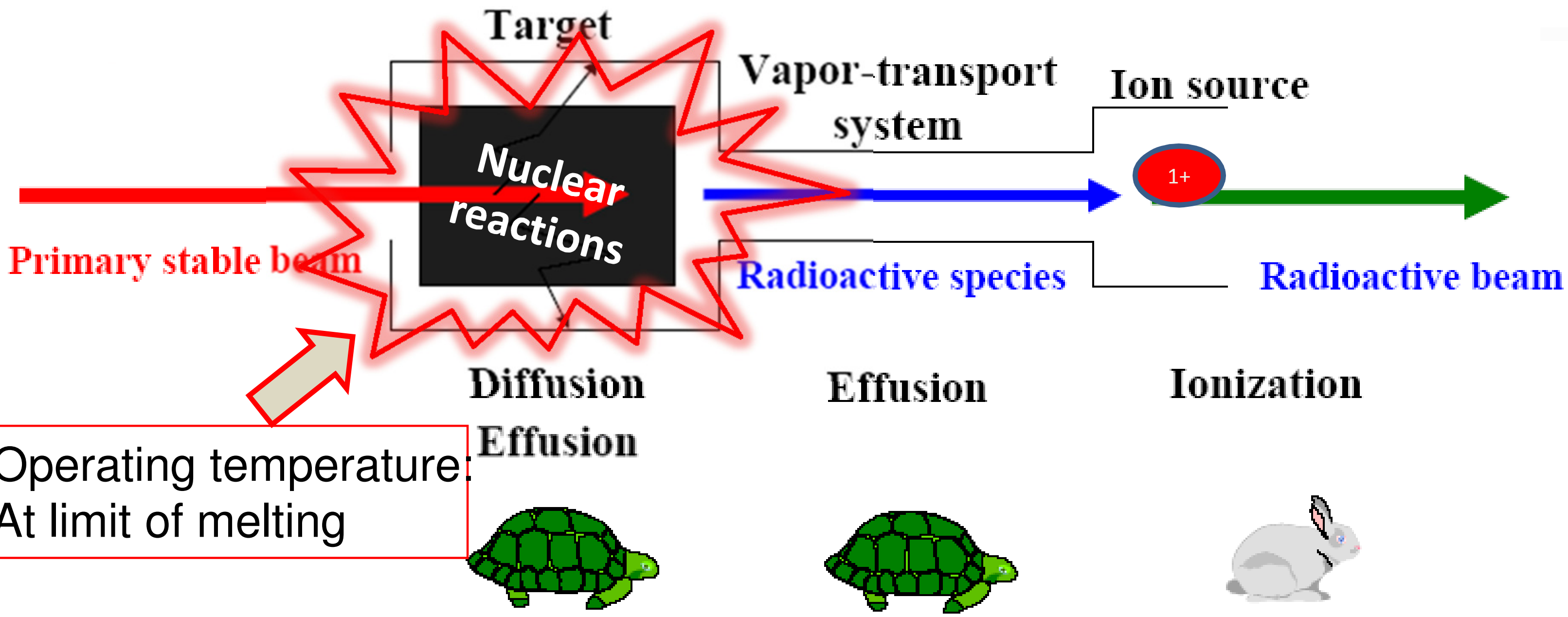
Production and study of neutron-rich nuclei

	Primary beam	Power on target	UCx target	Fission s^{-1}	Reaccelerator	Nominal energy AMeV A=130
HIE ISOLDE upgrade	p 1-1.4 GeV - 2 μA	2 kW	Direct (150g)	**$4 \cdot 10^{12}$**	SC Linac	5-10
SPIRAL2	d 40 MeV 5mA	200 kW	Converter (4000g)	**10^{13}** 10^{14}	CIME Cyclotron	5
SPES	p 40 MeV 200 μA	8 kW	Direct (30g)	**10^{13}**	ALPI SC Linac	10

Synergy & complementarity

will offer to the European nuclear physics community up-to date facilities to improve the knowledge of nuclei

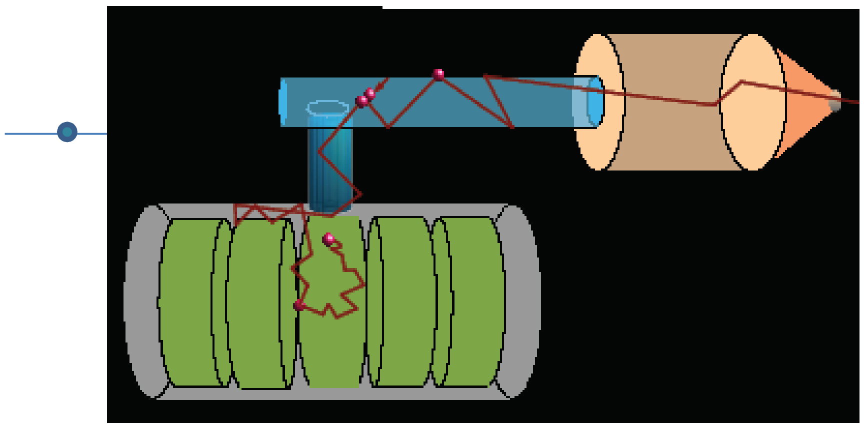
ISOL production process



Operating temperature:
At limit of melting

Release mechanisms:

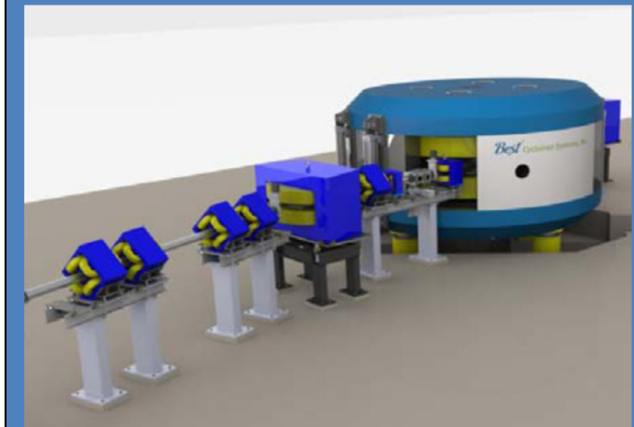
- ✓ In-grain diffusion
- ✓ Inter-grain effusion
- ✓ Free effusion/adsorption
- ✓ Ionization

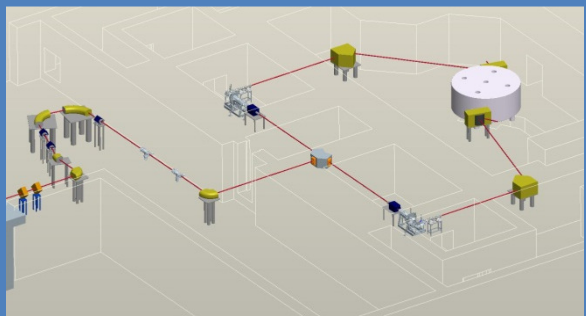


SPES second generation ISOL facility: 10^{13} f/s

Driver:

'Commercial' cyclotron





Production Target:

NEW CONCEPT !
(Multi-foil UCx target)

Post Accelerator:

Normal conductive RFQ

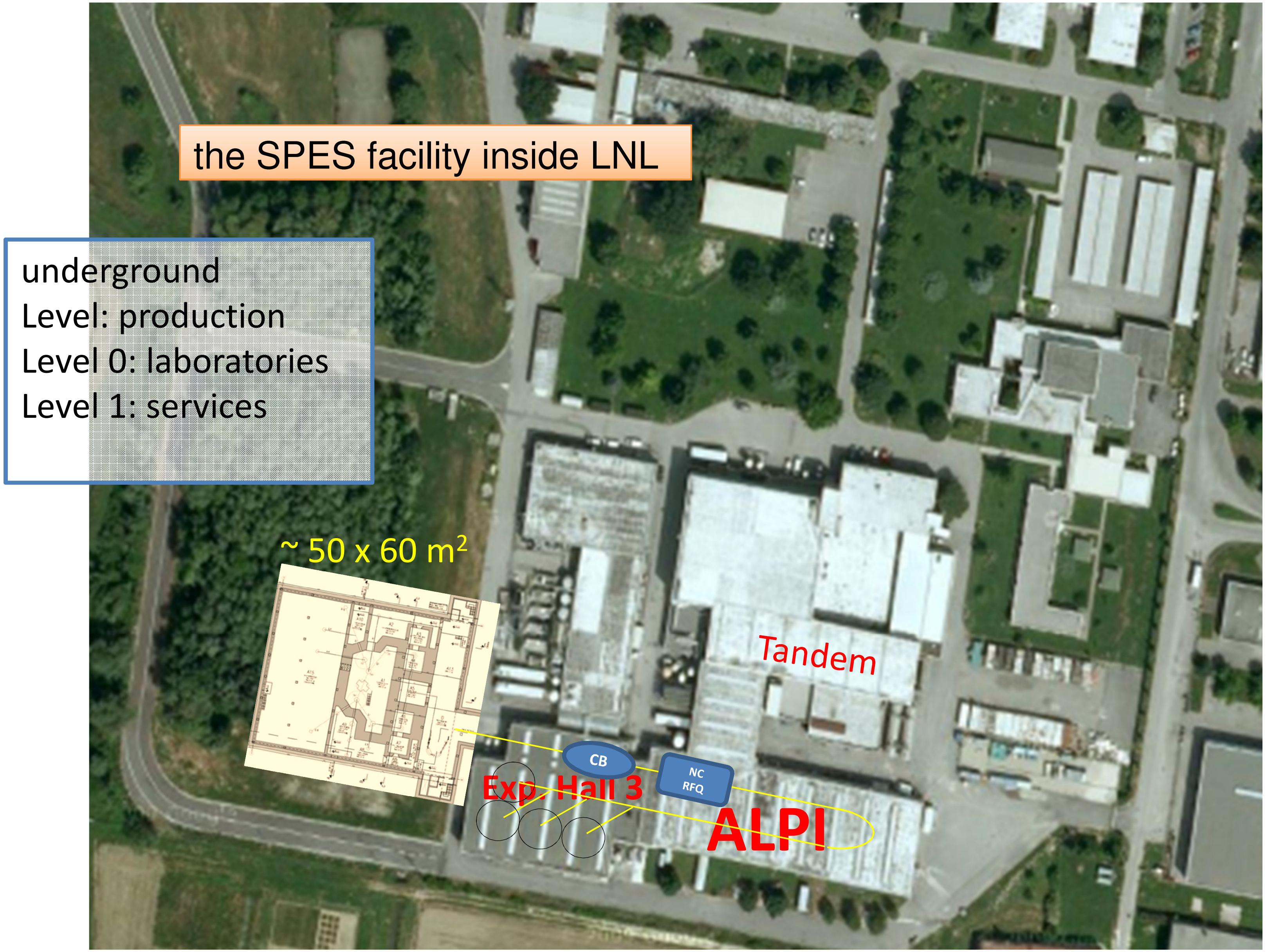
(new development)

&

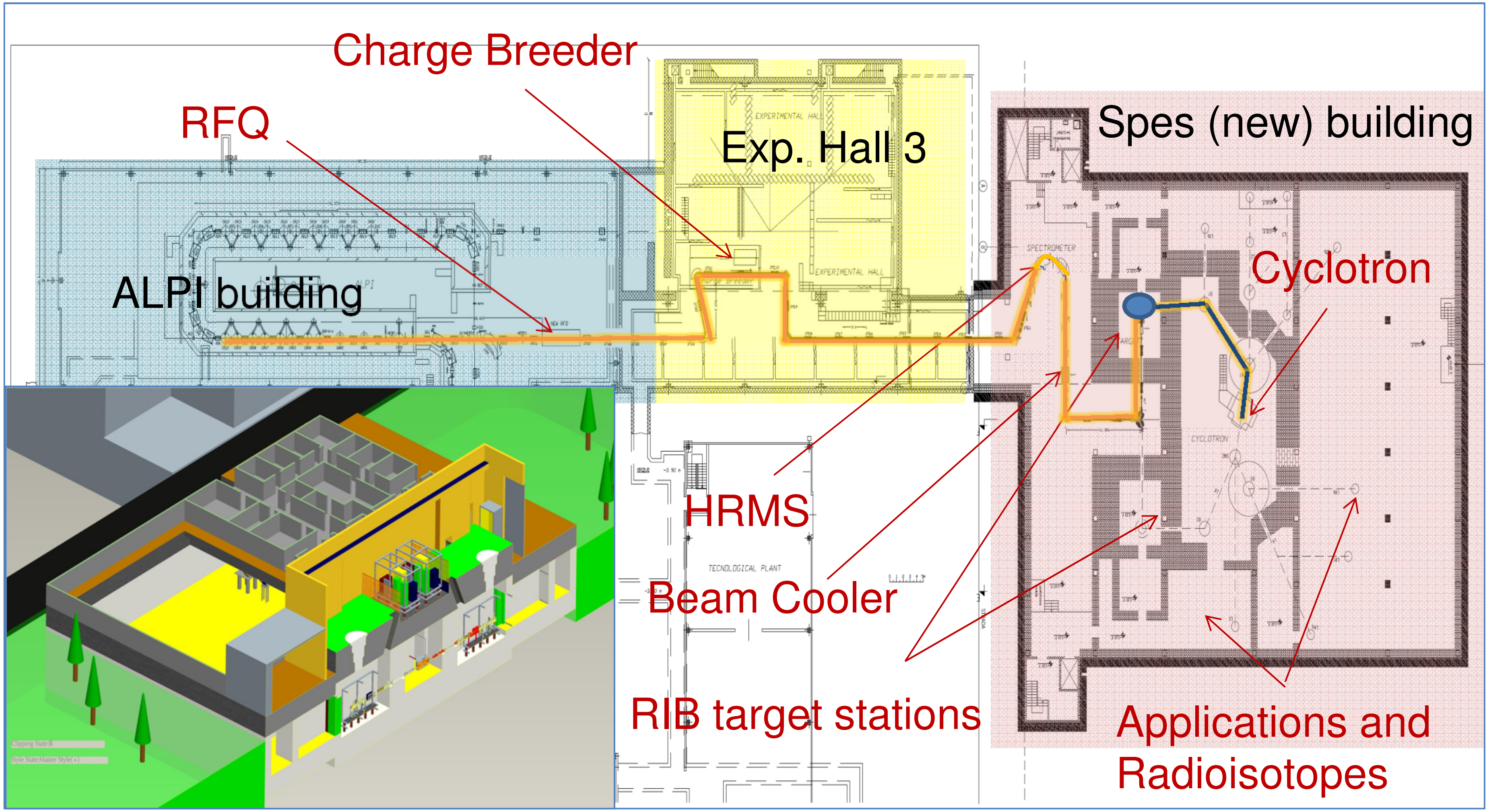
Alpi existing complex

Final energy: 10 AMeV at A=130

SPES Facility Layout

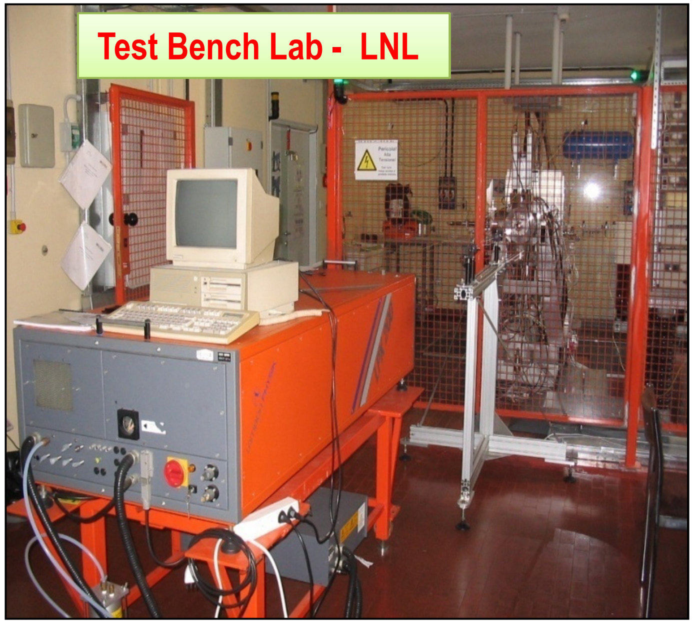


SPES layout:


Charge Breeder
RFQ
Exp. Hall 3
Spes (new) building
ALPI building
Cyclotron
HRMS
Beam Cooler
RIB target stations
Applications and
Radioisotopes

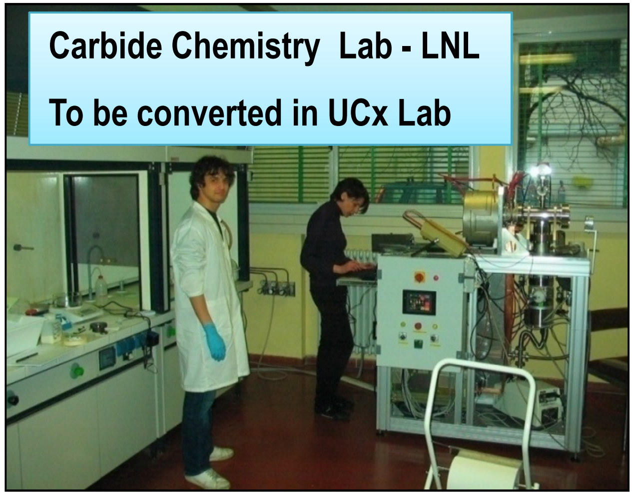
The ISOL SPES Laboratories

High Temperature Lab - LNL



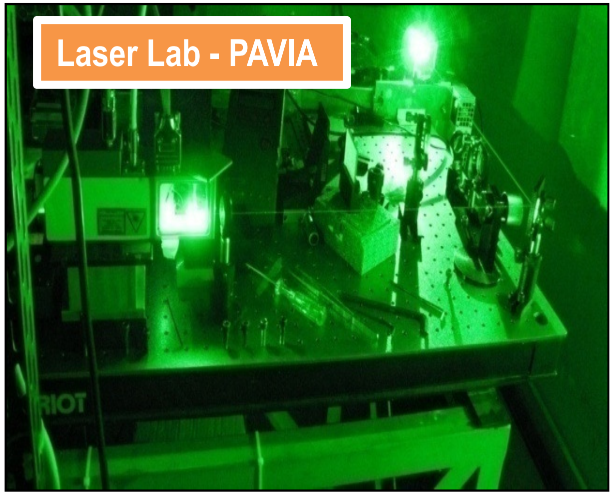
Test Bench Lab - LNL

UCx Chemistry Lab - Uni PADOVA



Carbide Chemistry Lab - LNL

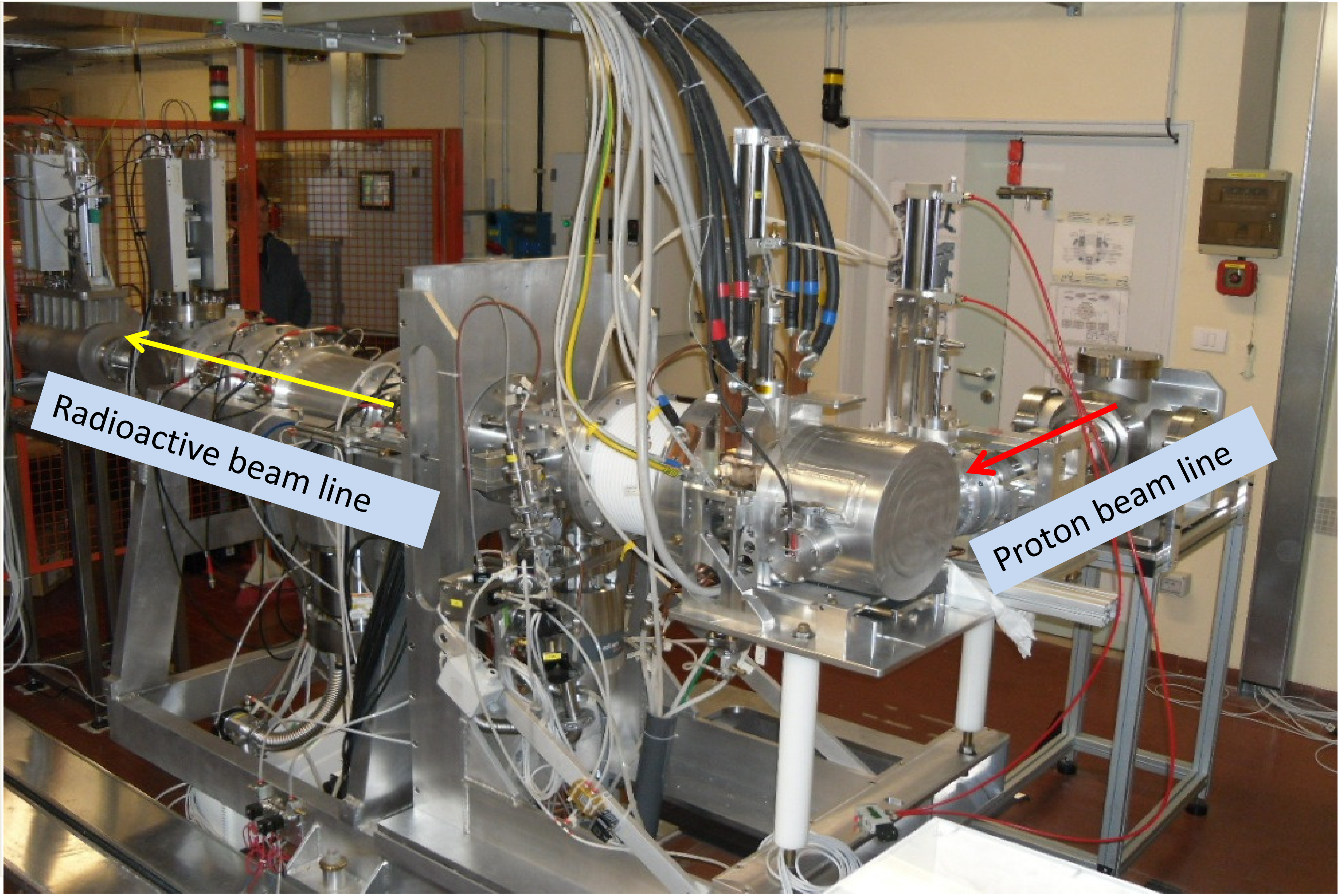
To be converted in UCx Lab



Laser Lab - PAVIA

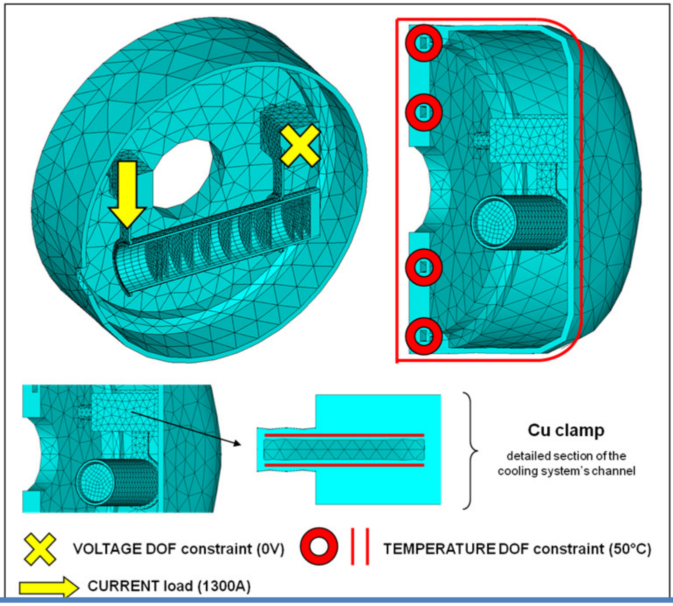
The SPES Front end

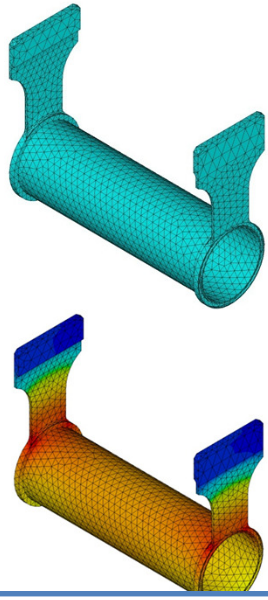
(SPES - ISOLDE collaboration)

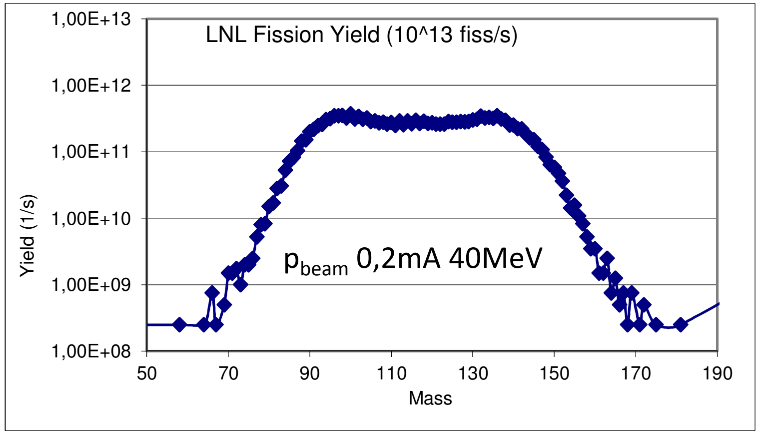


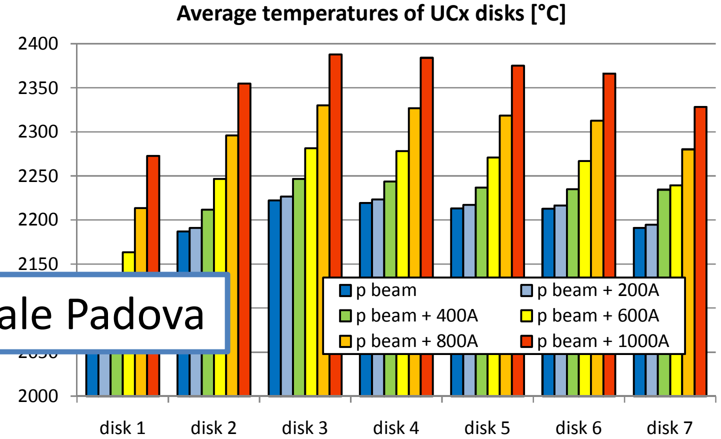
NEW DIRECT TARGET CONCEPT to operate with 10kW proton beam

The SPES choice: optimize the Direct Target design and material production to reach 10^{13} fissions/s

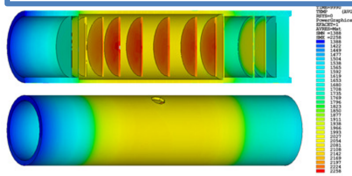


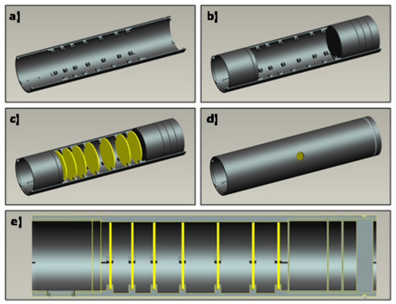


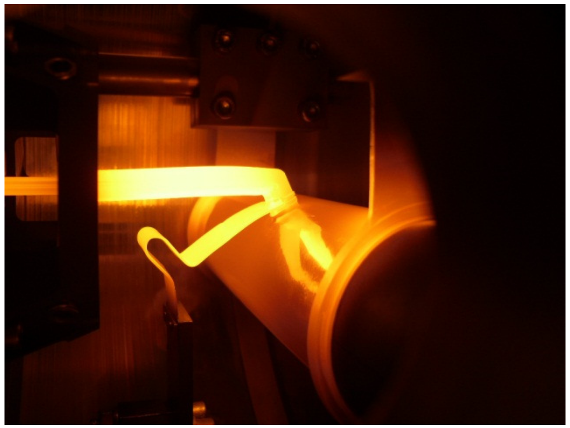


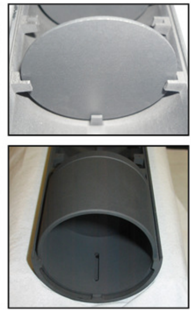


Collaboration with ENEA-Bologna and Ingegneria Industriale Padova

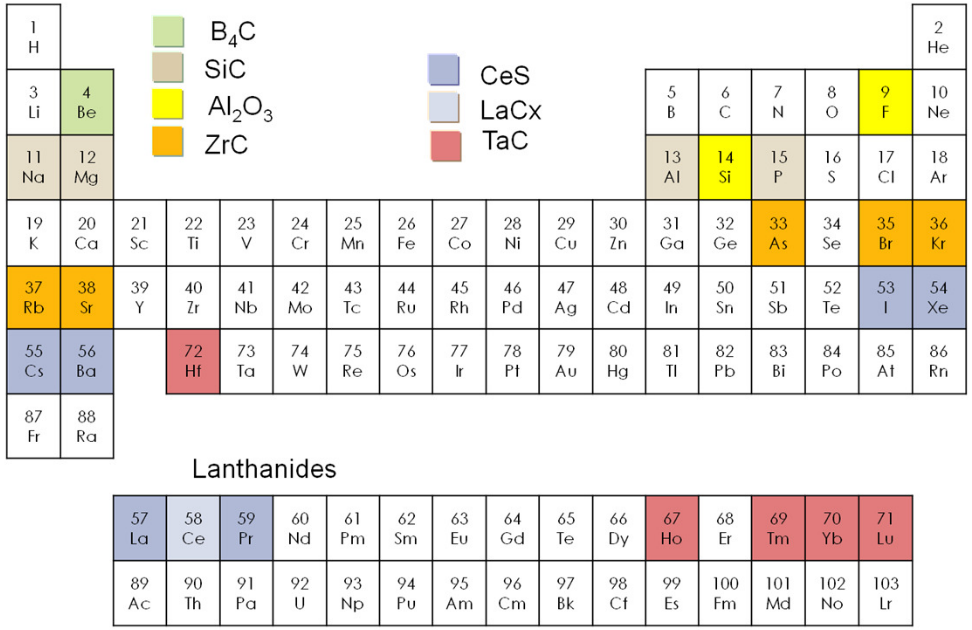




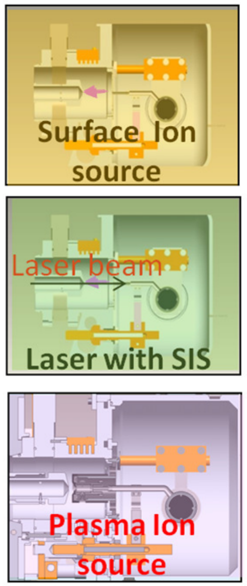


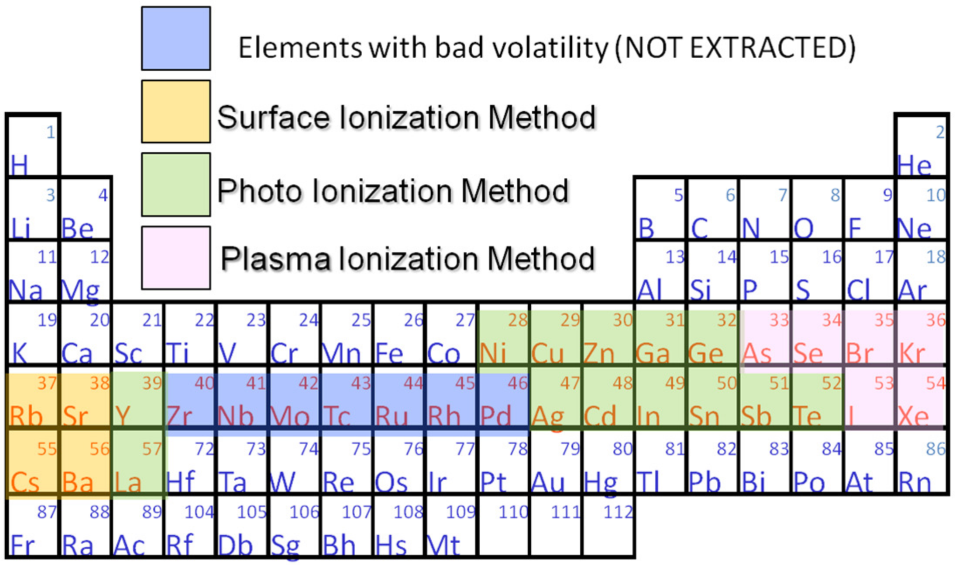


Targets developed for SPES ISOL facility allow to produce a variety of beams in the proton-rich and neutron-rich area



UCx



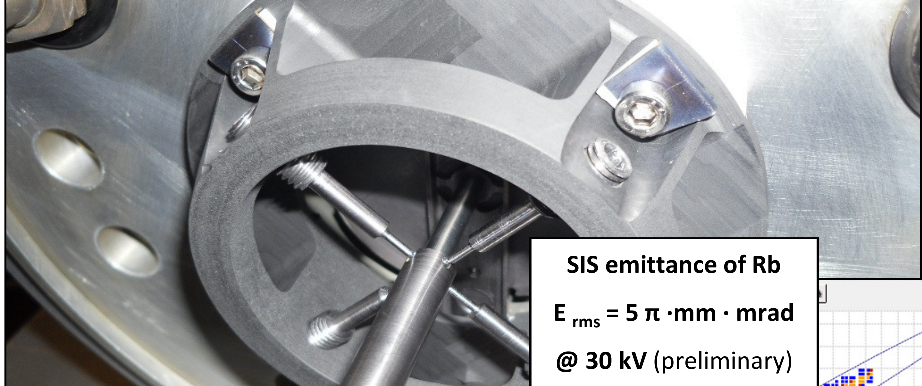


Main fission (p-> ^{238}U) fragments

The BAD VOLATILITY elements are produced and trapped in the target. These elements are highly required for nuclear medicine applications.

The SPES Ion Sources

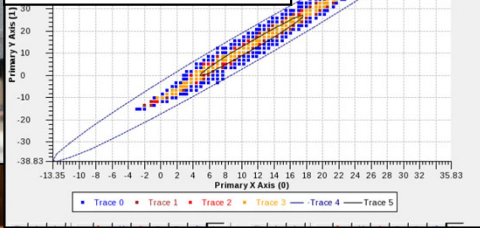
Surface Ion Source (SIS)

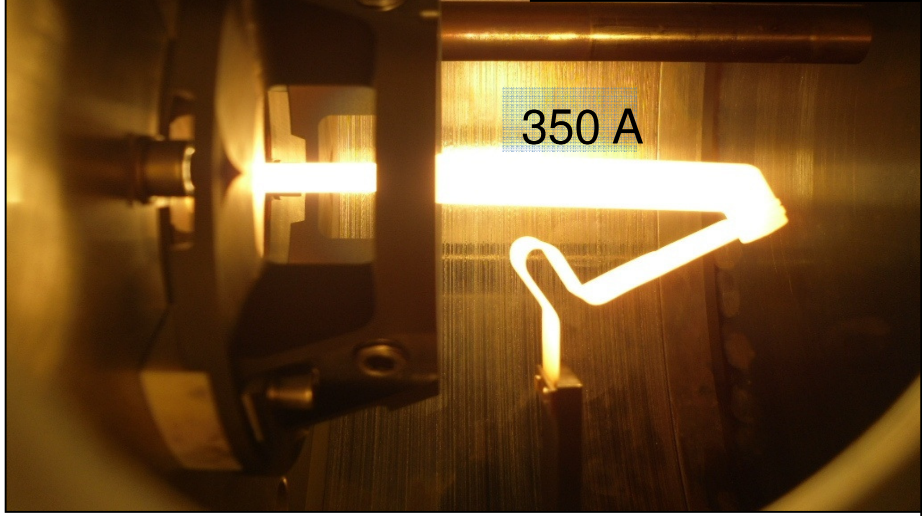


SIS emittance of Rb

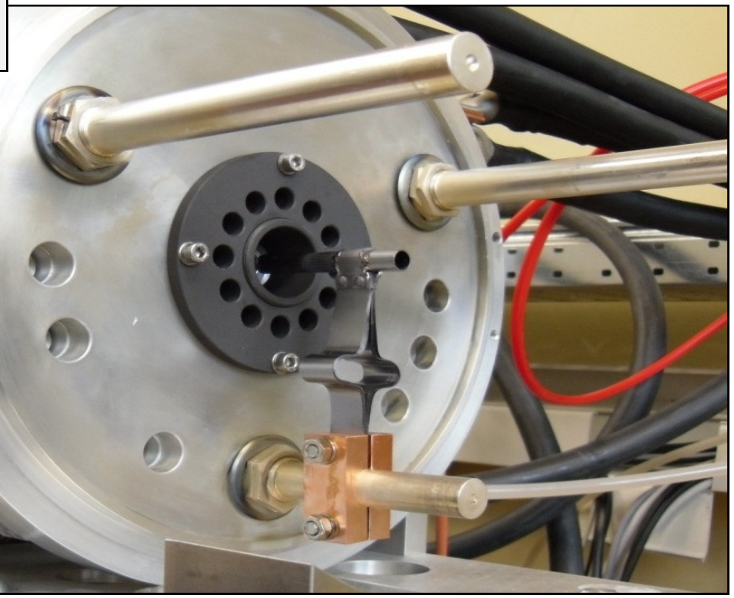
$E_{rms} = 5\ \pi \cdot mm \cdot mrad$

@ 30 kV (preliminary)



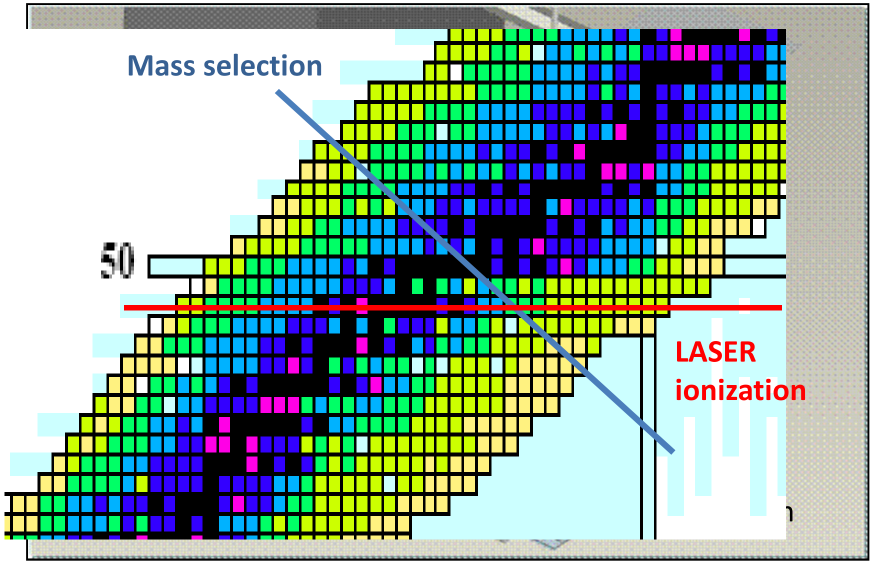


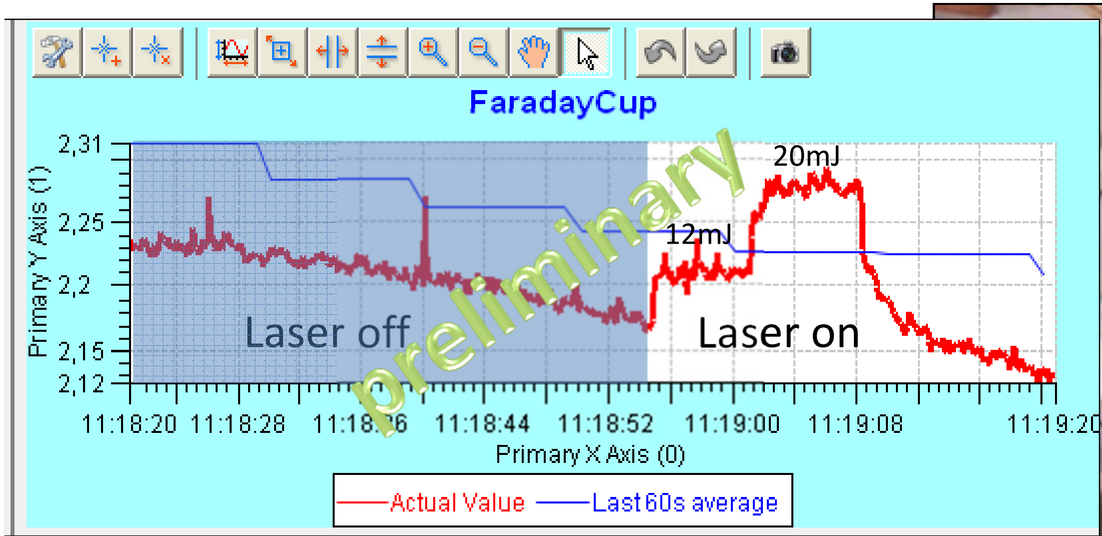
Plasma Ion Source (PIS)

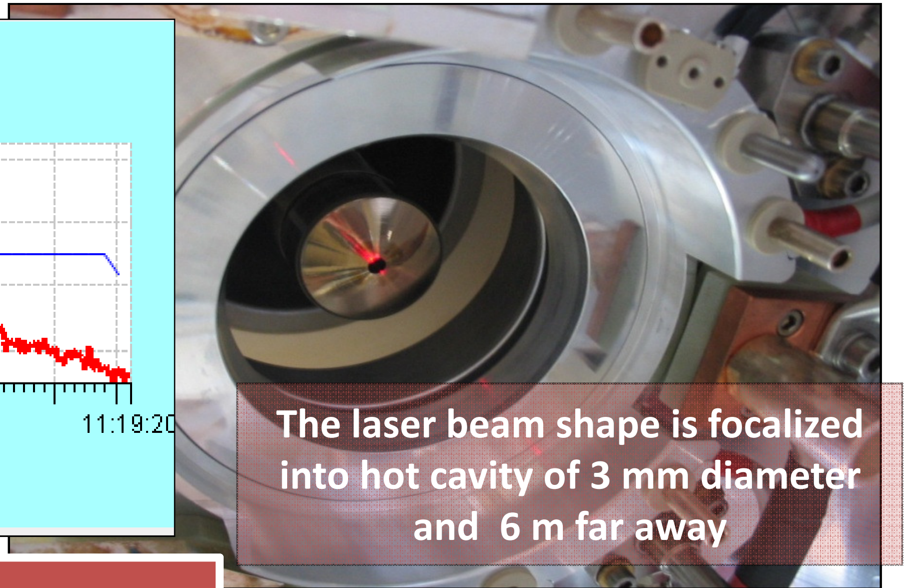


Laser test at LNL with excimer

Aluminum ionization with a single wavelength

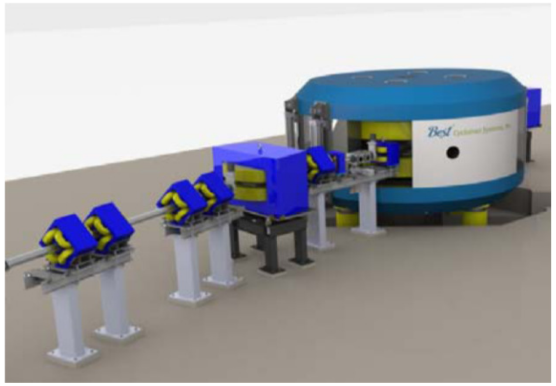






Collaboration with INFN-PAVIA

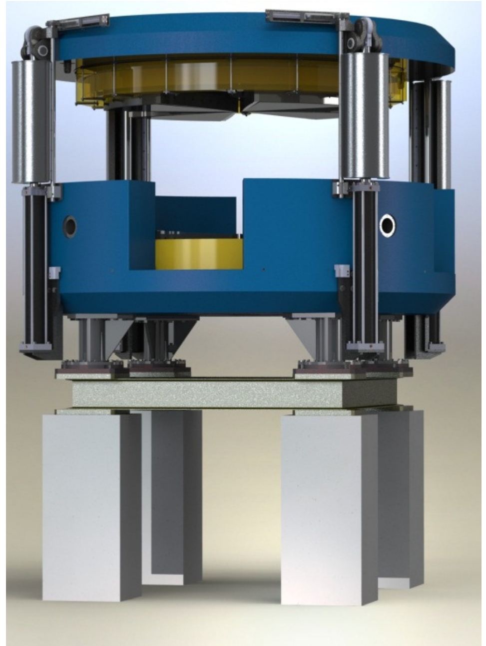
70p Best Cyclotron



BEST 70 MeV Cyclotron	
Accelerated Particle	H-
Extracted Particle	Protons
Energy	35-70 MeV (variable)
Current	> 700 uA (variable)
Extraction System	**By stripping → simultaneous dual beam extraction**
Injection System	Axial Injection → External Multicusp Ion Source 15-20mA DC
Main Magnet	B_{max} = 1,6 T Coil current = 127 kAt Power supply = 30 kW 4 sectors, deep valley
RF System	2 resonators Frequency= 58 MHz Harmonic mode=4 Dissipated Power=15 kW per cavity DEE voltage=60-80 kV
Operational Vacuum	2 e -7 mbar

Main Dimensions
Diameter = 4.5 m
Height= 1.7 m
Weight = 210 tons

70p Best Cyclotron



70p Magnet in Baltimore.

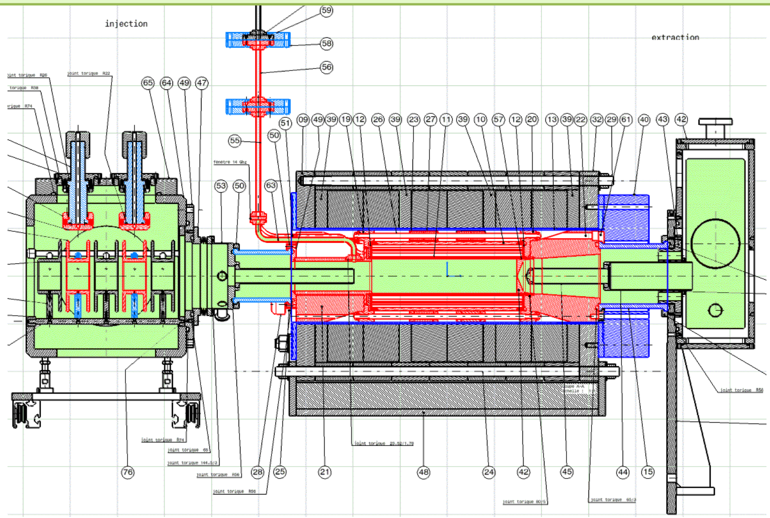
Machining is planned to be completed in December 2012. Cyclotron will be completed in factory in late 2013.

Magnet construction in Japan

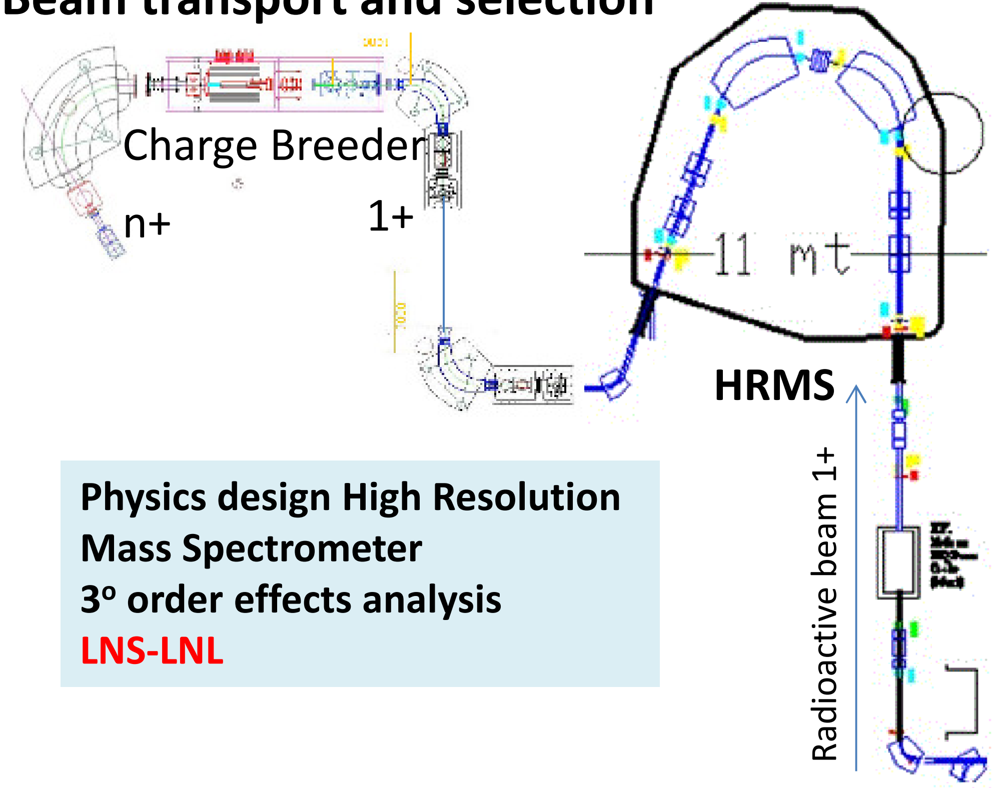
Radioactive Beam transport and selection

Development of an upgraded POHENIX booster
Part of MoU GANIL_SPIRAL2 – INFN_SPES

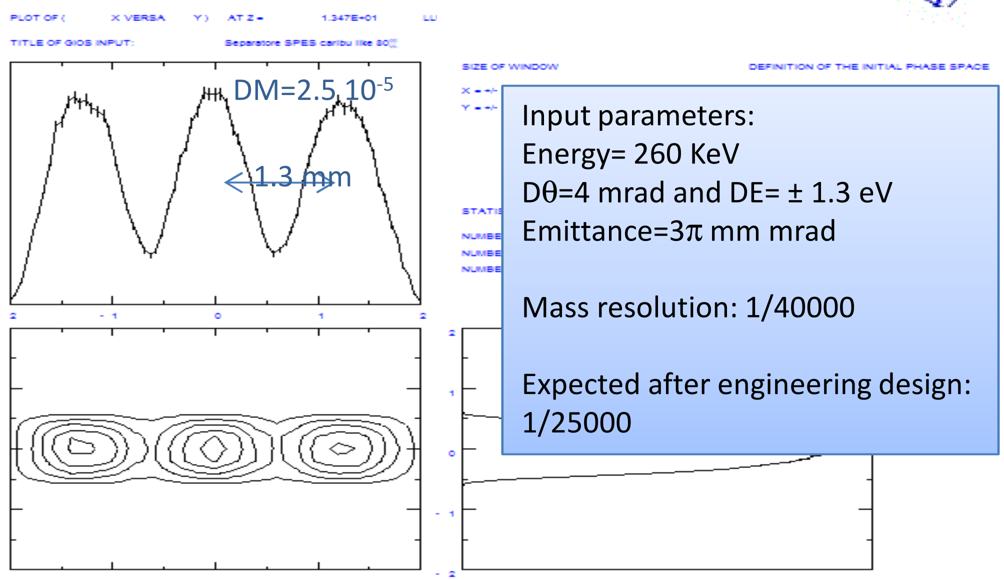
2010 Preliminary measurements
2011 Conceptual design and schedule definition
2012 Design
2013 Construction
2014 Commissioning



INFN-GANIL MoU:
INFN: neutron converter for SPIRAL2
LPCS: Charge Breeder for SPES



Physics design High Resolution Mass Spectrometer
3° order effects analysis
LNS-LNL



Input parameters:
Energy= 260 KeV
Dθ=4 mrad and DE= ± 1.3 eV
Emittance=3π mm mrad

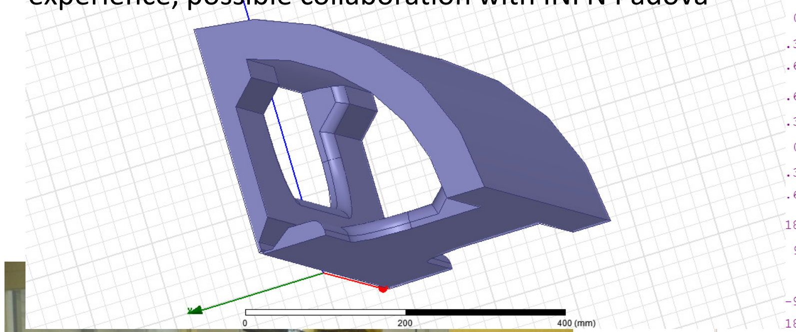
Mass resolution: 1/40000

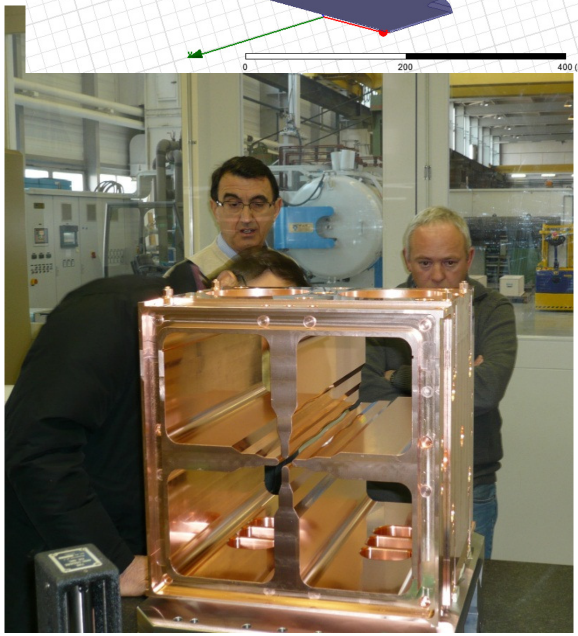
Expected after engineering design:
1/25000

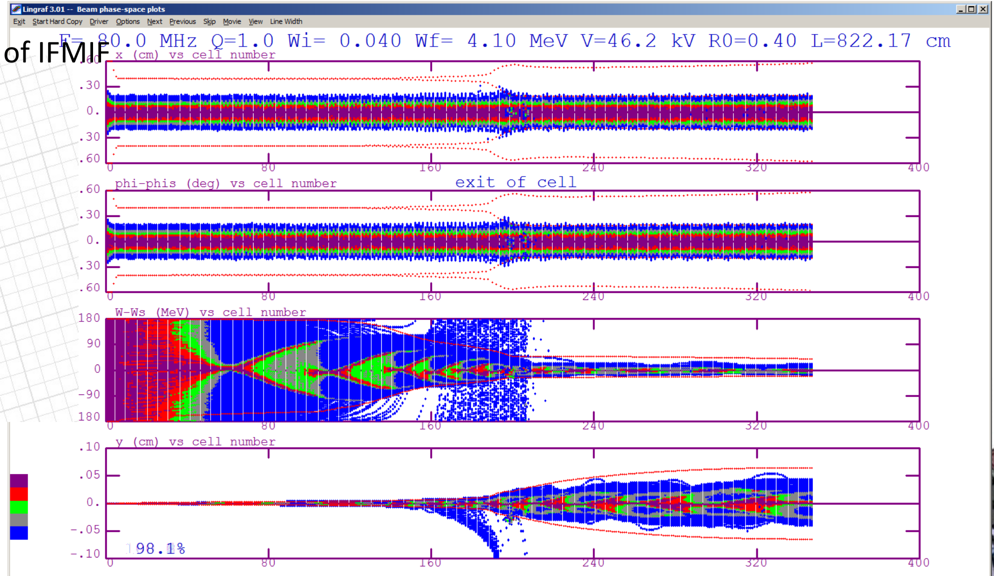
Pre-acceleration by normal conductive RFQ

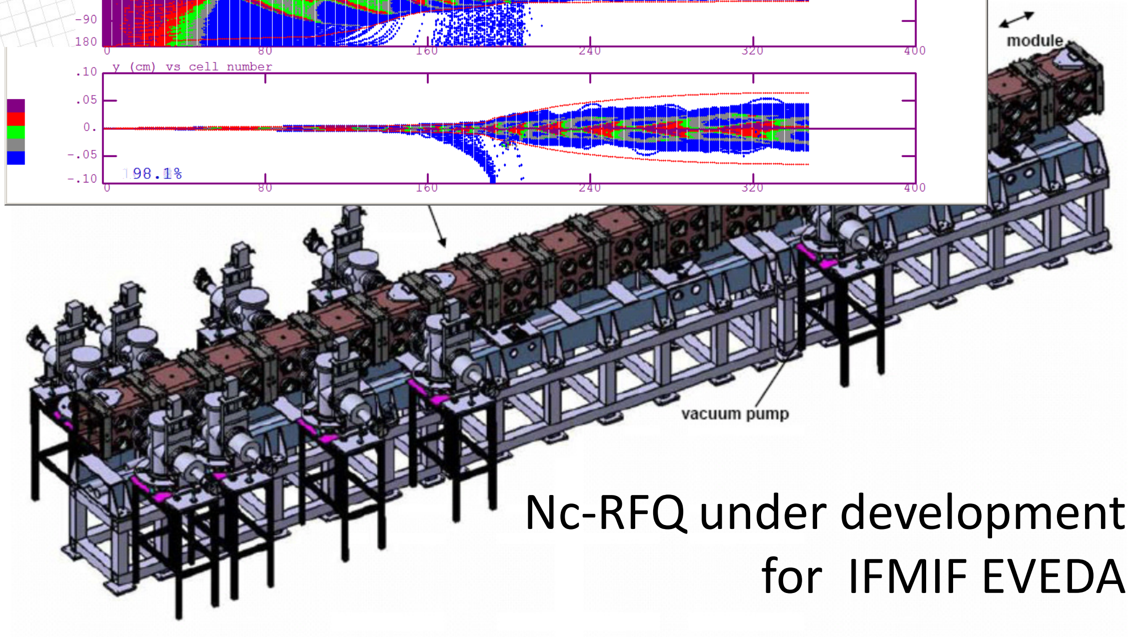
- Energy 5.7 –> 585.7 KeV/A (A/q=7)
- Beam transmission >95%
- Length 822 cm intervane voltage=46kV
- RF power Ladder 89 kW Q=9000
- DB Electronics amplifier 100kW CW 80 Mhz as SPIRAL2 RFQ can be used
- Mechanical design and realization, taking advantage of IFMIF experience, possible collaboration with INFN Padova

To enter the beam into ALPI a pre-accelerator is needed. A solution was studied based on the IFMIF-EVEDA technology.









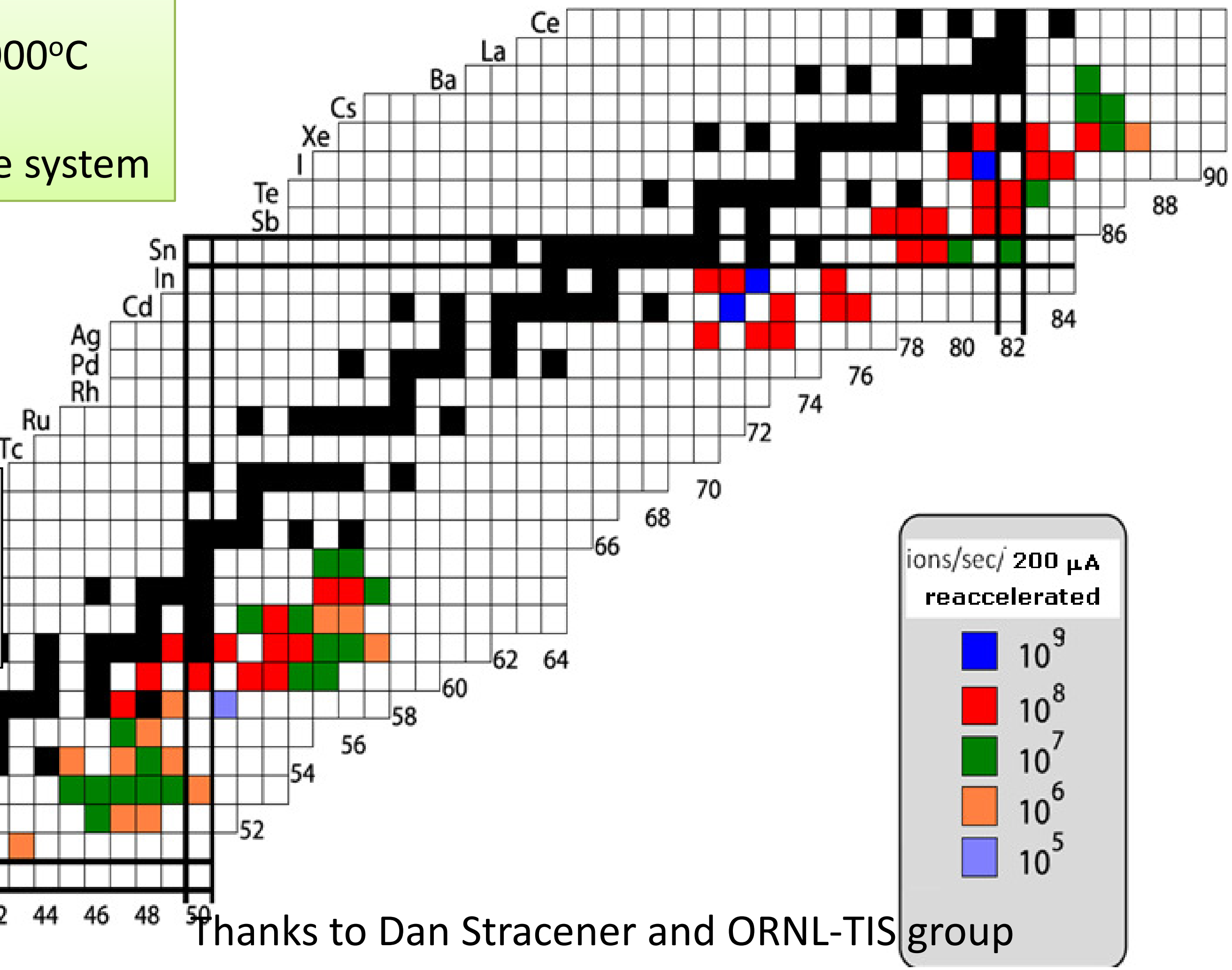
Nc-RFQ under development for IFMIF EVEDA

On-line SPES Target
Test experiment at ORNL

Experiment 2010-2011

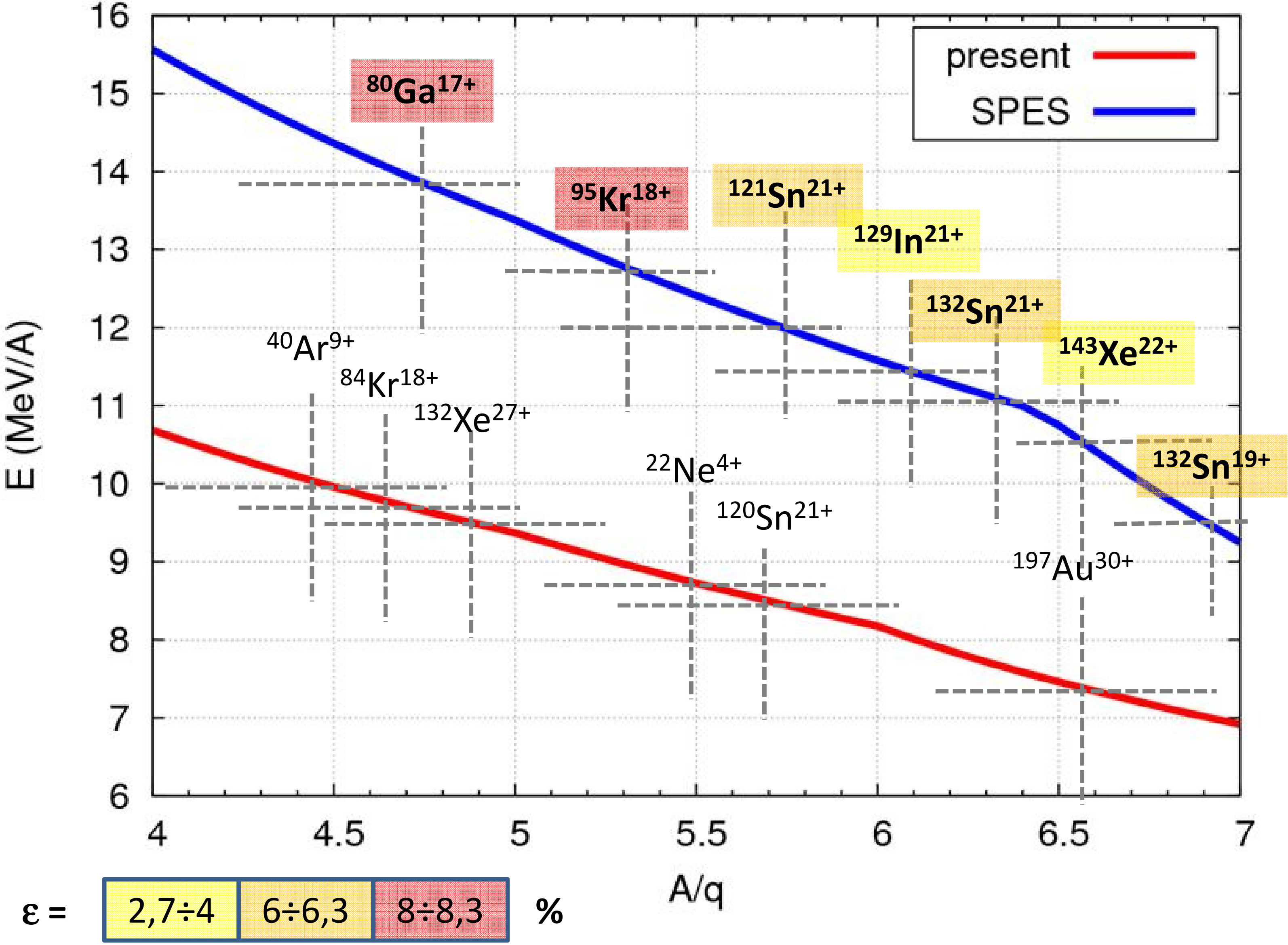
Proton energy 40MeV
ISOL target operated at 2000ºC
Plasma source 1+
Isotopes measured at Tape system

For **expected beam on target,** data are scaled to:
200 microA proton current
2-5% 1+→ N+ & RIB transport efficiency



Thanks to Dan Stracener and ORNL-TIS group

SPES Final Performance (Phoenix charge- bred beams)



SPES collaboration network

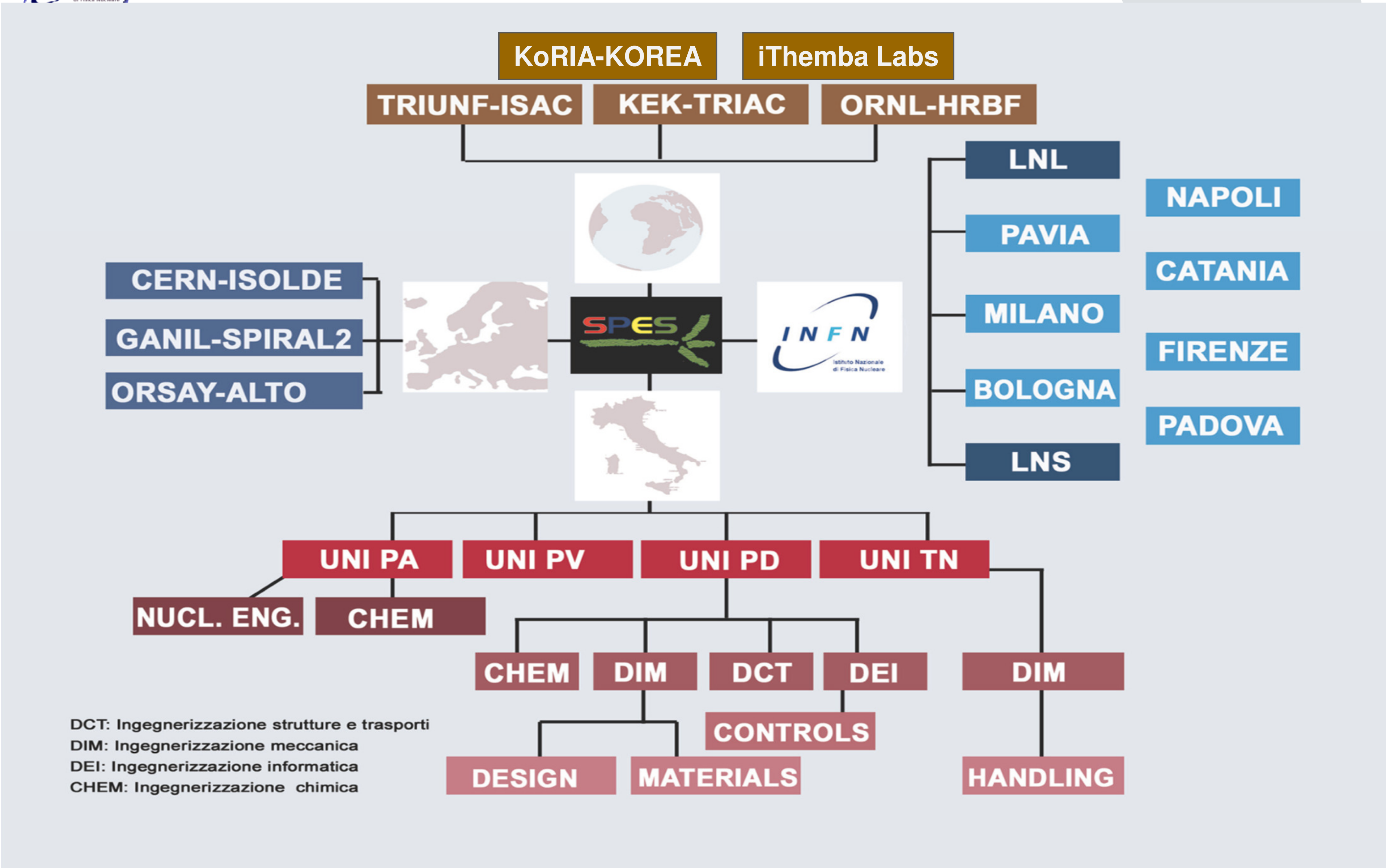
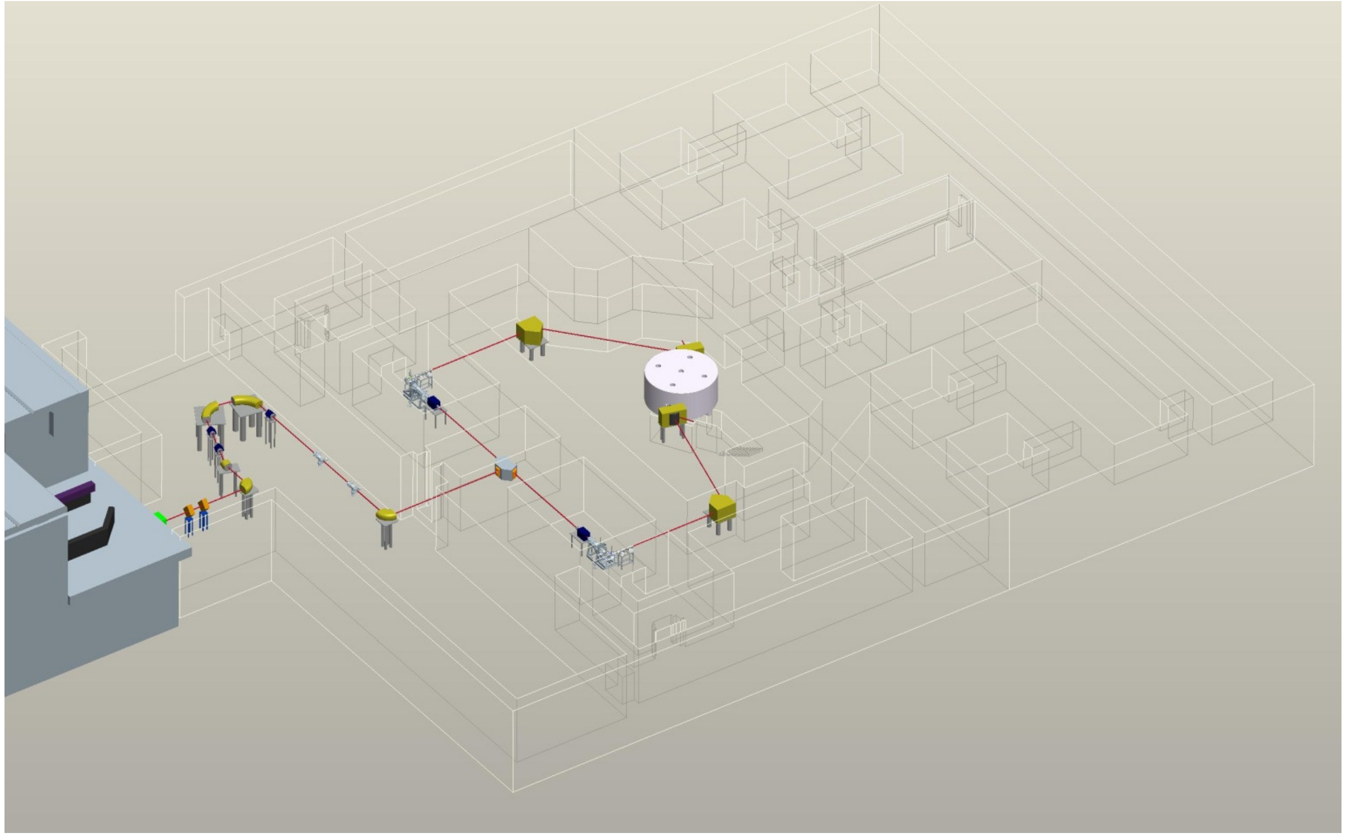


Fig. 3.25: Rete delle collaborazioni di SPES.

SPES Schedule September 2012

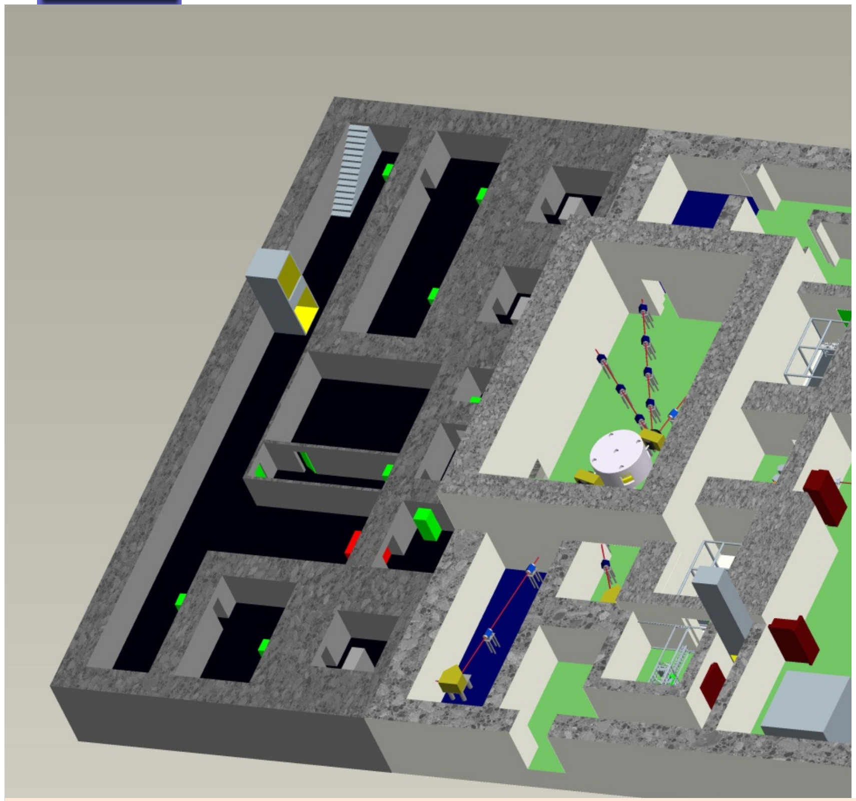
	2010	2011	2012	2013	2014	2015
50 Meuro	10	0.5	**14**	**11**	**14**	**2**
Main item	cyclotron		**Building Reaccel**	**RIB transp Reacceler.**	**UCx lab RIB transp Reaccel**	**commissioning**
Facility preliminary design completion						
Prototype of ISOL Target and ion source						
ISOL Targets construction and installation						
Authorization to operate and safety	Cyclotron operation			UCx operation		
Building's Tender & Construction	building project					
Cyclotron Tender & Construction						
Alpi up-grade & pre-acceleration						
Design of RIB transport & selection (HRMS, Charge Breeder, Beam Cooler)						
Construction and Installation of RIBs transfer lines and spectrometer						
Complete commissioning						



SPES Project

APPLICATIONS

Radio-isotopes for medicine



LARAMED Facility:
Production of radionuclides of interest for medicine using the SPES cyclotron

IAEA- Coordinated Research Project (CRP)

Accelerator-based Alternatives to Non-HEU Production of Molybdenum-99/Technetium-99m

IAEA Consultant meeting, July 26-29, 2011
IAEA Headquarters Vienna, Austria
(HEU: high enriched Uranium)

$^{100}Mo(p,2n)^{99m}Tc$

application forms on **http://www-crp.iaea.org/**

INFN – ARRONAX:

New target technology for the production of radionuclides

Development of new radiopharmaceuticals of copper-67/64

Development of new radiopharmaceuticals of rhenium-188

Investigation of the biological effect of alpha radiation

INFN – BEST Theratronics:

Production of Mo-99/Tc-99m at clinical levels

Direct Production of Tc-99m by p+^{100}Mo

Production via UCx Target (p-induced fission)

Evaluated Total cost: 20Meuro (Lab. Extension)

SPES Neutron facilities

LINCE: Legnaro Italian Neutron CEnter

Integral neutron production at SPES Cyclotron

Proton beam= 70 MeV, 500 μA

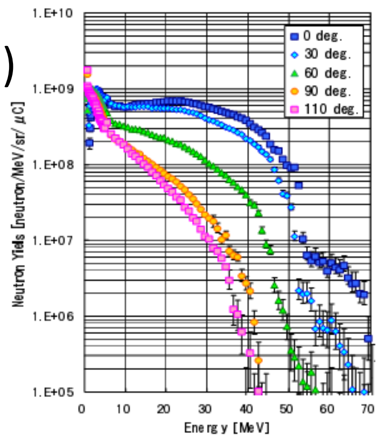
Target = W 5mm

Energy region (MeV)	Sn (n/s) $\sim 6 \cdot 10^{14}$ s^{-1}	**Φ_n @ 2.5 m (n cm^{-2} s^{-1})**	**Φ_n @ 1 cm (n cm^{-2} s^{-1})**
1 < E < 10	$\sim 5 \cdot 10^{14}$ s^{-1}	5×10^{8}	3×10^{13}
10 < E < 50	$\sim 1 \cdot 10^{14}$ s^{-1}	1×10^{8}	$6\text{x}10^{12}$

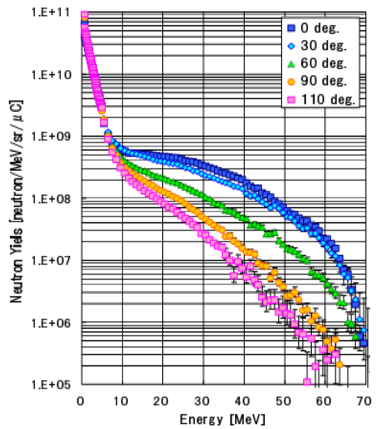
Neutron spectra for 70 MeV protons on different targets

Union for Compact Accelerator-based Neutron Sources

C(p,xn)



W(p,xn)



SPES Neutron facilities

LINCE: Legnaro Italian Neutron CEnter

LIFAN
(Legnaro Intense FAst Neutron facility)**:**

- SEE Single Event Effect used for electronics' irradiation
- DIRECT proton irradiation facility

scope:
The facility produces a beam similar to the **atmospheric spectrum** (limited to 70MeV) and allows to study the behavior of complex systems subjected to neutrondamage.

FARETRA
(FAst REactor simulator for TRAnsmutation studies)
Moderated neutron facility with Neutron spectra similar to Gen IV reactors

scope:
The facility reproduces a **spectrum typical of a fast neutron fission reactor** to perform measurements of integral cross sections of fission and capture of

- minor actinides (MA),
- short-lived fission fragments (FF)

and activation measures of structural parts and materials for cooling for Generation IV fast reactors.

third meeting of the UCANS collaboration

UCANS

The Union for Compact Accelerator-driven Neutron Sources
July 31 st to 3rd August,
Bilbao, Spain

Conclusions

- **SPES is a competitive project for the production of radioactive beams by ISOL method**
- **is part of the NUPECC long range plan and operate in sinergy with the european facilities for Nuclear Physics**
- **is involved in the europen collaborations ENSAR and NUPNET; was active in EURISOL design.**
- **allows the operation of an applied physics facility in parallel to the ISOL facility**
- **the construction phase is started with the participation of LNL, LNS and others INFN Divisions (Bo, Pv, Mi, Pd, Fi, Na, Ct)**

SPES laboratories are located in the main building and are available for visits